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AUTHOR	Chiu, Ming Ming
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ABSTRACT

This paper introduces a multi-dimensional, multi-level framework for analyzing students' social interaction and individual action during collaborative problem solving. Crossing the dimensions of problem knowledge distribution and degree of cooperation yields six possible social interactions: piecemeal guessing, joint construction, lecture, scaffolding, accepted demonstration, and automatic joint solutions. At the individual level, a three-dimensional space is constructed from the dimensions of evaluation of previous action, problem knowledge content, and interactive form; 27 individual actions are located within that space. Each social interaction consists of particular individual actions in representative segments of student collaborations in an algebra classroom. Educators can use this framework both as a collaboration and as an assessment tool. (Contains 15 references.) (ND)

ED 410 213

Cooperative Learning:

Social interaction categories and the individual actions that form them

Ming Ming Chiu

Administration, Curriculum, and Teaching Studies

University of California - Los Angeles

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The importance of cooperative learning is growing as US workers become integral members of projects rather than isolated assembly line specialists (Reich, 1992). Schools must adapt to the demands of our students' future work sites by helping them collaborate successfully to build understandings of complex phenomena (NCTM, 1992). The diversity of our current students (and future work force) requires a teacher who can help them negotiate and capitalize on their differences to solve problems creatively. Although researchers have contrasted the outcomes of student groups along many macro-variables such as group size, gender, and ability (Good, Mulryan & McCaslin, 1992; Slavin, 1990), no one has fully specified how the participants' moment-to-moment individual actions constitute the cooperative processes involved in collaborative learning. This study explicates two levels of analysis for a) documenting individual actions and b) classifying segments of students' collaborative problem solving into interaction categories. Furthermore, I show how individual actions form each interaction category.

In this paper, I define individual actions, social interaction segments, and classroom activities as follows. Each individual action is a sequence of one person's words, motions and/or drawings bracketed by pauses or falling intonations. The following are all examples of actions: [shrugs his shoulders], "what do we do next?" and [writes "3 x 5 = 15" on the assignment sheet]. A person may perform one or more consecutive actions between the actions of other people (a turn). Simultaneous actions (e.g. an utterance with a gesture) are identified separately, but are treated as one action in the analysis. Sequences of these actions form two types of social interaction segments, cohesive and piecemeal. In a cohesive interaction segment, each action evaluates the previous action supportively or critically (except for the first action in a segment).[1] Consider the following example.

[1] Since this paper is concerned with the participant's subjective understandings and interactions, the evaluation is based on the researcher's perceived intent of the person, not the apparent content of the action. For example, Ana and Sean are having a conversation in which Sean misheard Ana's proposal. He then criticized it with information

Sean: If you took the helicopter, you could go at 90 miles an hour.

Ana: But it slows down at the end

Ana criticizes Sean, so these two turns are a part of a cohesive interaction segment.[2] In contrast, piecemeal interactions are series of actions in which the following action does not evaluate the previous one. Consider the following example:

Sean: If you took the helicopter, you could go at 90 miles an hour.

Bob: I'd drive it upside-down.

Since Bob does not evaluate Sean's utterance, these two utterances are not part of a cohesive interaction.[3] Finally, these segments form specific classroom activities in a teacher's lesson plan, such as teacher demonstration, small group discussion, etc.

INDIVIDUAL ACTIONS AND THEIR INTERACTIVE PROPERTIES

Cooperative group researchers have argued that students playing out particular roles (Cohen, 1986) or using specific strategies (Barnes & Todd, 1977; Cazden, 1988; Slavin, 1990) increase the benefits of working together (or hinder the group's progress). While playing a role, a student uses particular strategies. Productive roles, each of which all students should eventually master, include facilitator (elicit information, promote group harmony), proposer (contribute new ideas), supporter (justify and elaborate ideas), critic (identify weaknesses, qualify original ideas), reporter (summarize progress). However, a single action may encompass multiple roles and strategies. Consider for example, a student responding to a suggestion to add the time and the speed with "do you think we could multiply them instead?" This student is

that actually supports her proposal. Sean's action would still be identified as a criticism, not a supportive action. Intentions are difficult to read, but simple affirmations ("yep"), rejections ("no"), and conjunctions ("but," "so") often point to the intended evaluations of the previous action.

[2]Contrast the simplicity of determining coherence based on evaluation against past attempts to determine cohesiveness based on reference (cf. Halliday & Hasan, 1976). In the above example, Sean's utterance refers to Ana's utterance through the use of a conjunction ("but") and a pronoun ("it") that refers to a previous noun ("train") used by Ana (i.e. a cataphoric pronoun).

[3]Bob's use of "it" to refer to the helicopter would satisfy the reference definition of coherence, but his utterance does not contribute to a coherent problem solution trajectory.

simultaneously a critic identifying a problem area, a proposer suggesting a new idea, and a facilitator both eliciting information and softening criticism (through a question rather than a statement). Researchers have not systematically examined the multiple functions of individual actions. In this section, I examine the interactive properties of individual actions along three dimensions. Then, I locate different actions within this multi-dimensional space. Critical vs. supportive evaluations, new contribution vs. repetition, and questions vs. statements are the initial contrasts along dimensions that I will label evaluation of previous action, knowledge content, and interactive form.

Interactive properties of individual actions

The evaluation of the previous action dimension characterizes how the current speaker assesses the previous action. After a person proposes an idea (e.g. "two hours times six miles per hour is ten"), one can support it entirely (+), reject at least part of it (-), or ignore it (0). Supportive actions (+) reinforce the direction of the current problem solving approach through acknowledgments ("yep"), justifications ("cause it only moves for two of the four hours"), criticism of alternatives ("times four hours assumes it's always moving"), etc. Moreover, they promote friendly social relationships through positive social face (Brown & Levinson, 1987), especially if the participants invest themselves in their ideas.

Criticism (-) includes both partial and total rejection. Partial rejection accepts the general framing of the proposal but notes errors ("twelve, not ten"), suggests related alternatives ("how about four hours times six?") or challenges some parts ("why two hours?"). In contrast, total rejection denies the validity of the whole frame of the proposal ("we have to find the acceleration, not the distance"). Since the distinction between partial and total rejection is difficult to delineate, I have chosen to group them together. Criticisms alter the problem solving trajectory by identifying flaws and opening alternatives. As before, if the previous speaker identifies his ideas with himself, cognitive rejection of the idea may also threaten psychological rejection of the person (especially without accompanying face-saving measures [Brown & Levinson, 1987]).

Finally, unresponsive actions (0) do not evaluate the previous action at all, initiating new topics instead ("I'm hungry").[4] Unresponsive actions draw the conversation away from the previous speaker's solution approach entirely and pose a greater threat to the social relationship. They may present the worst threat to social face by ignoring the previous speaker's action, judging it as worthy of comment. So, participants who initiate more new topics (through unresponsive actions) to which others respond show greater authority and control.

Knowledge content characterizes the problem knowledge displayed during the interaction and forms a continuum that includes non-overlapping contributions, overlapping contributions, synonymous repetitions, partial repetitions, exact repetitions, and null actions. Consider each type of knowledge content in response to the phrase "two hours times six miles per hour." A non-overlapping contribution provides problem information without repeating any part of any previous action, e.g. "that'll give us the distance." In contrast, an overlapping contribution adds new information in combination with information from a previous action, "so the train moves twelve miles in two hours." In general, contributions (C) are new problem solving ideas or actions introduced into the collaboration and indicate moments of potential progress in the problem solving. Contributions include new goals, proposals, justifications, consequences, critiques, alternatives, and summaries. Tracing the contributions provides a map of the group's problem solving route. Meanwhile, repetitions (R) repeat the knowledge content of previous actions (not necessarily the immediately preceding one). Synonymous repetitions elaborate previous actions, but do not add significant new information, "two hours multiplied by six miles per hour." Meanwhile, partial and exact repetitions repeat part or all of a previous action

[4]One possible distortion may arise from a person presenting a series of proposals one after another in one turn. This analysis assumes that the speaker only evaluates the last action. If the person responds to any proposal except the last one, that act is coded as unresponsive (0). This is an issue for conversations in which people lay out a series of

precisely, "two times six" (partial)[5] and "two hours times six miles per hour" (exact). Repetitions can indicate the speaker's level of understanding and degree of agreement with previous contributions. Finally, null actions do not contribute specific, new problem-related information and do not repeat old information, "yeah." (Null actions can be repeated, but I always classify them as null actions, never repetitions.)[6] Since null actions are typically brief, they can serve as backchannel actions that provide feedback without interrupting the current speaker.

The interactive form dimension describes the different degrees of encouragement for audience participation and includes at least three possibilities: statements, questions, and commands. Statements (S) declare information unintrusively, without eliciting participation from others. Virtually all the sentences in this paper are statements in which a subject precedes a predicate, e.g. "five times seven is thirty-four." In contrast, questions (Q) invite audience participation intrusively by articulating an action/information gap for them to fill, thereby requesting an action, problem information or an evaluation. Typical questions end with rising intonations, e.g. "what's two times six?" Finally, commands (!) demand obedient audience participation without asking for their evaluation. Typical commands begin with verbs, "multiply two times six!"

The degree of interaction that these three forms initiate also vary within each form as well. The following types of statements (S) elicit different degrees of participation: definitive vs. uncertain, summary vs. goal, and directives. Definitive statements discourage further discussion of what the speaker perceives to be a known truth ("two times six is twelve") while uncertain statements encourages input on the validity of the statement ("two times six seems like twelve").

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alternatives, for example in structured, management decision-making.

[5]Partial repetitions must maintain the same meaning of the previous action, so negations by omission are contributions. "These birds can fly for two miles non-stop" is a contribution, not a repetition of "none of these birds can fly for two miles non-stop."

[6]Note that actions in off-task conversations are not labeled contributions. Instead, they are labeled as null content

Likewise, summary statements tend to close interactions by articulating what the group has already accepted ("so we got twelve miles by multiplying two hours and six miles per hour") whereas goal statements encourage interaction by presenting a target towards which the group can work ("we need to find the distance"). Finally, directive statements present information that implies a directive toward action (Searle, 1969). The directive "two times six can't be ten" suggests that the audience recalculate the product of two and six. In short, definitive summaries, definitive goals, uncertain summaries, uncertain goals, and directives are all statements, but encourage successively greater participation.

Rhetorical, tag, choice, and open questions (Q) also initiate different degrees of interaction. Although the form of a rhetorical question invites responses ("can't you do anything right?"), the speaker knows the answer and does not expect a response. Tag questions follow statements and anticipate simple acknowledgments, "two times six is twelve, right?" Meanwhile, choice questions offer multiple possibilities from which the audience can select, "should we add or multiply?" Finally, speakers asking open questions do not restrict the answers and invite a greater variety of responses, "what should we do next?" Rhetorical, tag, choice, and open questions invite successively greater participation.

Finally, commands (!) can also elicit different degrees of interaction. Although most commands demand audience action, blocking commands demand audience inaction, e.g. "wait!" Detailed commands specify particular actions, "measure the length of the box." Finally, open commands request general input from the audience, "give me your opinion." Blocking, detailed, and open commands demand increasingly greater audience participation.

The three major categories of interactive forms (statements, questions, and commands) generally encourage different degrees of audience participation, but they also vary within each

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actions because they do not contribute to the problem solution.

category. Future analyses may incorporate finer distinctions, but this paper only uses the major categories within each interactive dimension of analysis to define individual actions.

Individual Actions

This section describes twenty-seven individual actions and their locations within the space created by the three dimensions of evaluation, knowledge content, and interactive form (see Table 1).

Table 1. Individual actions organized along three dimensions, evaluation of the previous action, problem knowledge content, and interactive form

Evaluation of Previous Action	Knowledge Content	Interactive Form		
		Statement (S)	Question (Q)	Command (!)
Unresponsive (0)	Contribution (C)	Announcement (0CS)	Proposal (0CQ)	Sudden order (0C!)
	Repetition (R)	Fixation (0RS)	Echo request (0RQ)	Echo command (0R!)
	Null (N)	External action (0NS)	General request (0NQ)	Starter (0N!)
Supportive (+)	Contribution (C)	Supportive addition (+CS)	Supportive proposal (+CQ)	Implementation command (+C!)
	Repetition (R)	Verification (+RS)	Check of others (+RQ)	Repeat commands (+R!)
	Null (N)	Acknowledgment (+NS)	Supportive request (+NQ)	Execution command (+N!)
Critical (-)	Contribution (C)	Critique (-CS)	Counter-proposal (-CQ)	Counter-order (-C!)
	Repetition (R)	Repeat Critique (-RS)	Exact challenge (-RQ)	Repeat counter-order (-R!)
	Null (N)	Denial (-NS)	General challenge (-NQ)	Halt (-N!)

I will begin with individual actions that ignore the previous action (0) and contribute new ideas (C): announcements, proposals, and sudden orders. Speakers using these actions attempt to close off the previous discussion/series of actions (if there were any) and/or initiate new (possibly parallel) conversations. As discussed earlier, unresponsive actions (0) can rupture the social fabric by rejecting the previous action (if any) as unworthy of comment. Announcements (0CS) are statements that initiate a topic of discussion ("we have to find the distance") or that occur during brainstorming ("we can try graphing it"). Proposals (0CQ) serve the same purpose, but also elicit evaluations from others, e.g. "are we finding the distance?" Finally, sudden orders (0C!) demand implementation from the audience without requesting an evaluation, e.g., "find the distance" and "multiply two times six."

Now consider unresponsive actions (0) and repetitions (R): fixations, echo requests, and echo orders. By using these actions, the speaker reconsiders an earlier rejected or ignored idea without regard to the current conversation. Fixations (0RS) indicate construction of new understanding of the old idea "distance is rate times time!" or an attempt to do so "rate times time ..." without intruding upon others. In contrast, echo requests (0RQ) encourage others to consider a past idea, "rate times time equals distance?" while echo commands (0R!) demand that the audience act on a past idea, "multiply the rate and time again!"

The last set of unresponsive actions (0) are null actions (N) that ignore the previous action but do not specify another direction for the conversation: external actions, general requests, and starters. External actions (0NS) indicate that the speaker is attending to something other than the problem solving activity, e.g. [looking out the window] or singing a tune "skiddly dee dop, da dee dop, da dee dop." Meanwhile, general requests (0NQ) invite others to participate in a new series of actions "what are we supposed to do?" or to summarize "what did we do?" Finally, starters (0N!) initiate activities without specific instructions, "get to it!"

In short, people can ignore the previous action by contributing new ideas (announcements, proposals, and sudden orders), repeating past actions (fixations, echo requests, and echo orders), and performing null actions (distractions, general requests, and starters).

Next, I specify supportive evaluations (+), beginning with contributions (C): supportive additions, supportive proposals, and implementation commands. This set of actions justifies the previous action, articulates additional beneficial consequences and/or continues with an appropriate action. Supportive additions (+CS) indicate that the speaker understands and accepts the previous action (according to his/her own interpretation), e.g. "that gives us the distance." Speakers may choose supportive proposals (+CQ) that suggest less certainty to test their ideas or to test the other group members' understanding, "so that gives us the distance?" Finally, speakers use implementation commands (+C!) to order others to perform consequent actions, "so multiply two and six."

People can support the previous action (+) by using repetitions (R) that indicate their understanding: verifications, checks of others, and repeat commands. Verifications (+RS) may confirm understanding of the previous action, "twelve", indicate that the speaker is trying to make sense of it "times two ... is ... twelve," or repeat the previous action to check its validity, [presses the following calculator keys: 2, x, 6, =] "twelve!" To test whether the other group members understand the previous action, a person may use checks of others (+RQ), typically through synonymous or partial repetitions, "hours times miles per hour is miles?" People use repeat commands (+R!) to pass along the instruction to another person "José, multiply two by six," to repeat an ignored command, "I said multiply two by six," or to repeat an incorrectly implemented command, "multiply two by SIX."

People can also support previous actions (+) through null actions (N): acknowledgments, supportive requests, and executions. By using an acknowledgment (+NS), a person can indicate acceptance of the current speaker's idea without interrupting (backchannel feedback), e.g. "uh-huh" and [nods]. Supportive requests (+NQ) include continuation requests and tag questions. Continuation requests are open questions that ask for the next step in the solution, "what's next?" while tag questions ask for confirmation of the previous action, "right?"(expecting a "yes" or "no" response). Finally, execution commands (+N!) affirm previous proposals (CQ) and demand that others to act upon them, "do it."

In short, people can support the previous action by contributing new ideas (supportive additions, supportive proposals, and implementation commands), repeating past actions (verifications, checks of others, and repeat commands), and performing null actions (acknowledgments, supportive requests, and executions).

Finally, consider critical evaluations (-), beginning with contributions (C): critiques, counter-proposals, and counter-orders. Critical contributions present new ideas that reject at least part of the previous action by providing an alternative, revealing a flaw in the reasoning, or showing an undesirable consequence. When using a critique (-CS), a person objects to the previous action by presenting an alternative "two PLUS six," a revealed flaw, "the train only goes four hours," or an unwanted consequence, "but by then the train has passed the car." Counter proposals (-CQ) soften critical suggestions by inviting others to evaluate the criticism, "shouldn't we multiply by two since the car only goes for two hours?" As discussed earlier, the question form may also indicate low confidence in the suggestion "should we multiply by two ..." In contrast, a counter-order (-C!) not only criticizes the previous action but expects the audience to act immediately on a new order, "do two times six instead of four times six ."

People can also criticize (-) through repetitions (R): repeat critique, exact challenge, and repeat counter-order. Repeat critiques (-RS) reject the previous action by repeating an earlier action, "it's only going four hours," or by noting the violation of an earlier premise, "you said that it was only going four hours. This tactic should be extremely persuasive if the audience had agreed upon the earlier premise. Exact challenges (-RQ) soften premise violations "didn't you say that it was only going for two hours?" or question the validity of the previous action by requesting clarification, "it's going for two hours?" If a person issues a repeat counter-order (-R!), he/she has repeated an order over someone's criticism, "do two times six anyway!"

People also criticize (-) through null actions (N): denials, general challenges, and halts. Denials (-NS), the mirror images of acknowledgments, provide negative backchannel feedback, "uh-uh" and [shakes her head]. Unlike exact challenges, general challenges (-NQ) do not specify the area of concern, "why?" Finally, people use halts (-N!) to prevent someone from performing an action, "Stop!"

In short, people can criticize the previous action by contributing new ideas (critiques, counter-proposals, and counter-orders), repeating past actions (repeat critique, exact challenge, and repeat counter-order), and performing null actions (denials, general challenges, and halts).

SOCIAL INTERACTION CATEGORIES

Researchers have shown that students can work together in different ways (co-construction [Cobb, Yackel & Wood, 1992], scaffolding [Wood, Bruner & Ross, 1976], and jigsaw [Aronson, 1978]), but no one has created a complete classification of social interactions. My theoretical framework takes a step toward this goal by combining the two dimensions of knowledge distribution (cf. Forman & Cazden, 1985) and degree of cooperation (cf. Stodolsky, 1984) to produce a grid that locates different types of social interaction segments. Consider the problem of finding the roots of $x^2 - 1 = 0$. Each participant's knowledge of the problem may include virtually nothing ("what's a root?"), knowing something about the domain ("I have to find out what x is"), knowing some tools to use ("I want to isolate x on one side"), knowing the algorithm ("I can solve it by the quadratic formula), and knowing the solution and one or more algorithms ("The roots are 1 and -1. We can do it by solving for x, using the quadratic formula, or using the difference of squares formula $x^2 - a^2 = (x + a)(x - a)$."). A person who knows a solution algorithm for a problem treats it as an exercise to be solved with little effort. In contrast, a person who does not know a solution algorithm must exert significant effort and may not solve it at all. As a result, we expect different levels of problem knowledge to yield different social interactions. I classify students' problem knowledge during an interaction segment as either knowing how to solve the problem (algorithm(s) with or without the answer) and not knowing (all other levels of problem knowledge). In this paper, I will use the term "expert" for those who know a solution algorithm to the current problem and the term "novice" for those who do not. Since each of the four students in a group may fall into either knowledge classification, there are sixteen possibilities. However, these possibilities reduce to three major categories when considering the goals of the interactions: trying to solve the problem, ensuring that everyone understands the solution, and executing a solution algorithm. If no one knows a solution algorithm, then they try to solve the problem. However, if at least one person knows a solution, the goal may change to teaching the others. Finally, if everyone knows a solution algorithm, then they can simply execute an algorithm. (Afterwards, they can also discuss alternate solutions and look for relationships between different solutions.) In short, my knowledge dimension consists of three major categories: no one knows a solution algorithm (all novices), at least one person knows (at least one expert and one novice), and everyone knows (all experts).

Each person's degree of cooperation may range from independent to cooperative: working alone in private, displaying answers publicly, displaying reasoning processes, and interacting with other students' reasoning processes. All of these degrees of cooperation may occur in a single activity. For example, the students may work independently and arrive at an answer without saying anything to one another (absolute silence). Then they may exchange answers ("I got ten"). After they give different answers ("wait, I got six"), one or more students may show their reasoning ("I multiplied six miles per hour by two hours"). Finally, they may attempt a new solution in which they all contribute ideas, evaluate them, and build on them to construct a solution, step by step ("He's going at 10 miles an hour." "But you slow down" "Yeah, but only for a little bit" ...). Although Stodolsky (1984) classifies students who take turns displaying information (division of labor) as cooperative, I label only the last category as cooperative because it is the only one that requires moment-to-moment cooperation. In the other cases, individuals can act alone and the other students need not actively engage with the individual displays of information. In short, my cooperation dimension consists of two major categories: relatively independent and cooperative (Stodolsky [1984] prefers the term "completely cooperative").

Combining the knowledge distribution and degree of cooperation dimensions yield six interaction categories: piecemeal guessing, joint construction, lecture, scaffolding, accepted displays, and automatic joint solutions (see table 1).

Table 1. Six social interaction categories constructed from the two dimensions of knowledge distribution and degree of cooperation.

	Degree of Cooperation	
Knowledge distribution	Independent	Cooperative
All novices	Piecemeal guessing	Joint construction
At least one expert and one novice	Lectures	Scaffolding
All experts	Accepted demonstration	Automatic joint solutions

Composing social interactions from individual actions

We can determine the social interaction type by examining the individual actions within each interaction. Since the social interactions all correspond to a combination of knowledge distribution and degree of cooperation, we can examine how individual actions indicate properties along each of those dimensions.

Piecemeal guessing occurs when novices work relatively independently. Since no one knows a solution, we expect participants to contribute only bits and pieces of unconnected ideas and actions during short turns. These participants typically do not issue many commands (!) because they do not know a solution and the students generally share roughly equal social status (indeed, we expect students giving commands to have higher social status). Moreover, they do not cooperate, so we expect primarily unresponsive actions in the form of statements. Unresponsive actions (0) ignore the previous action and reduce the degree of cooperation. A statement (S) does not engage the other group members and allows them to ignore it more easily. In contrast, questions (Q) invite participation and commands (!) demand it. Consider the following segment in which the students are solving the cruise ship problem:[7]

A cruise ship left five hours ago traveling at twenty–two miles per hour. How far will it travel before you catch up with it in a helicopter traveling at ninety miles per hour?

EPA	KC	IF	Person	Actions
0	C	S	RA	Ninety miles divided by twenty–two.
0	C	S	CC	(12) It's less than three hours [looks at RA & MS]
0	C	S	MS	Ninety times five hours.
0	N	!	RA	Wait,
0	N	S		I got lost.
+	C	S		I got lost right here [left index finger taps paper near "90 x 22 = 1980"] when I was trying to multiply.
0	N	!		Wait.
+	N	!		Let me try to figure this out.

Each turn was one-action long except for RA's last turn, and they all ignored the previous speaker through unresponsive actions (0). RA supported (+) only her own previous actions. By using statements (S) rather than questions (Q), these students did not encourage one another to

[7]All transcript segments are from videotapes of an algebra class in an uban, public high school (Chiu, 1996).

evaluate their contributions. Finally, RA's two blocking commands (0N!) both reinforced her independent intentions and suggested her higher social status. In short, piecemeal guessing interactions primarily consist of short turns of unresponsive actions in the form of statements (primarily announcements: 0CS).

Joint construction occurs when novices are cooperating, building on each other's ideas to create a new understanding that none of them could articulate before the interaction. As with piecemeal guessing, we expect short turns and few commands because the participants lack a solution. In a joint construction however, the students cooperate with one another by evaluating one another's actions (+ and -), using repetition (R) to indicate their level of understanding, and asking questions (Q) to invite evaluations. Furthermore, students may voice unsupported denials (-NS) because the they are showing their general disagreement (cooperative) without providing any clear rationale (lack of knowledge). Consider the following joint construction segment in which students are finding the slope of a pile of beans in a box (talus slope problem). They had previously calculated the slope of two–dimensional lines, but not three–dimensional objects.

EPA	KC	IF	Person	Actions
0	C	Q	MS:	What's the slope?
+	N	S	RA:	I don't know!
+	N	S		I'm thinking. [laughs]
–	N	S	MS:	I'm just asking myself.
-	R	S	RA:	I don't know.
0	C	S		(4) I can't even picture this in my mind.
+	C	S	MS:	[holds her pen horizontally above the pile]

+	C	Q		What's across from it?
+	C	Q		What's going that way?
+	C	Q	RA:	From where?
+	C	Q		From the bottom?
+	N	S	MS:	Yeah.
+	R	S		From the bottom.
+	C	S	RA:	[Places ruler along the bottom of the box at the bean pile corner] It's like seven.

The short turns, absence of commands (!), and early null actions (N) suggested MS and RA's lack of a solution. Moreover, they were cooperating with each other as indicated by their evaluations of each other's actions (+ and -). MS also indicated her understanding by repeating RA's action (verification: +RS), and they asked for evaluations of their supportive proposals (+CQ). In particular, MS and RA built on each other's actions through supportive proposals and additions (+CQ and +CS). In short, joint construction segments include short turns with many evaluative actions (+ and -), verifications (+RS), questions (Q) and statements (S), but few commands (!).

During a lecture segment, an expert explains the solution to the others with little cooperation. As a result, the expert dominates the conversation with respect to total floor time, average turn length, and number of turns (if two or more novices join the conversation). The expert links supportive additions (+CS) together in a few long turns, occasionally laced with tag questions (+NQ). During more interactive lectures, the expert may issue commands (!) to the novices to engage them in the lecture (socially acceptable in this information-asymmetric interaction). In response, the novices may check their understanding and ask for clarifications. To check their understanding, they may use verifications (+RS), supportive proposals (+CQ), and supportive additions (+CQ), sometimes combined with tag questions (+NQ). The expert then acknowledges them (+NS), elaborates them with supportive actions (+CS) or criticizes them (-) and explains further through additional contributions (C). Novices may also ask for clarifications (supportive requests [+NQ], general challenges [-NQ], and exact challenges [-RQ]). They are not likely to criticize (-) the expert's explanation except indirectly through requests for clarifications (+NQ, -NQ, -RQ). Since the novices have no information-based authority, commands (!) issued by novices to the expert(s) indicate high social status in some other area. Consider the following lecture segment in which RA explains how to plot points on a graph to indicate a toy crocodile's location at different times:

[4/22 period 2 table 7 after 10:08:57]

EPA	KC	IF	Person	Actions
0	C	S	RA	[reaches over with pencil, points to a spot on C's graph paper] Okay,
+	C	S		you start at five.
+	R	S	CH	I start at five.
+	N	S		Yes.
+	C	S	RA	You start at five zero.
+	N	S	CH	Yes.
+	C	S	RA	And then you go to one.
+	C	S		And then at one,
+	C	S		you go to seven.
+	C	S	CH	So you point.
-	R	S	RA	So you go up to seven.
+	C	S	CH	So the point's here, [points to (1,7)]
+	N	Q		right?
-	N	S		No.

+	C	!	RA	Point at five first.
+	R	S		Five.
+	R	S	CH	Five.
+	N	S	RA	Okay,
+	R	S		then at one,
+	C	S		he will be at seven,
+	C	S		so that's up here.
+	C	S		So you put a dot there [points to (1, 7)].
+	C	S		And then when he's at two,
+	C	S		he's at nine.
+	C	S		So then you put a dot at nine.
+	C	S	CH	Right here.
+	R	S		Nine.

Using supportive additions (+CS), the expert RA explained the solution in long turns. The novice CH typically responded with backchannel confirmations, namely acknowledgments (+NS) and verifications (+RS). CH contributed a supportive addition (+CS) three times, but RA rejected (-) the first two. The first time, RA implicitly rejected CH's contribution by repeating his previous action (repeat critique: -RS). When CH elaborated his contribution in his second supportive addition, he asked RA to evaluate it through a tag question (+NQ). RA denied it flatly (-NS) this time and addressed his suggestion with an implementation command (+C!). Finally, CH's last supportive statement (+S) did not invite RA's evaluation. Since CH's last contribution continued RA's actions supportively (+C) and then verified (+RS) RA's last statement, RA did not need to acknowledge (+NS) CH's actions. In short, an expert dominates a lecture segment with supportive additions (+CS) in a few long turns, occasionally laced with tag questions (+RQ) and implementation commands (+C!). The novices typically respond with acknowledgments (+NS) and verifications (+RS), occasionally providing supportive additions (+CS) and supportive proposals (+CQ), and asking for clarifications (+NQ, -NQ, -RQ).

Lecture segments also appear in other types of activities such as static arguments and Jigsaw activities (Aronson, 1978). In a static argument, each person declares his/her position on different aspects of an issue without addressing those of his opponent, for example in debates ("tax cuts grow the economy" vs. "tax cuts take from the poor and give to the rich"). In effect, static arguments consist of alternating lectures. Unlike constructive arguments, participants in a static argument have fixed positions. They try to persuade one another (or a spectator audience) of their own superior position rather than seeking an amenable solution to all participants. If we relax the knowledge constraint from a person knowing the whole solution algorithm to knowing the portion of it articulated during the interaction segment, then Aronson's Jigsaw activity fits this category as well. In Jigsaw, each student is responsible for a different part of a single problem. After the students master their parts, they present their work in a series of lecture segments. Both static arguments and Jigsaw activities typically include alternating lecture segments.

In scaffolding interactions, the novices build the solution under the guidance of the expert. Unlike lectures, the novices construct a significant portion of the solution while deferring to the expert's authority. Empirically, novices dominate the floor time, but experts take more turns if two or more novices are participating. We expect the novices to contribute ideas and actions (C) in short turns, in the form of questions (Q) or statements (S) with tag questions (+RQ). As in lectures, novice critiques (-CS) of the expert(s) are unlikely. The novices' deference to the expert(s) also manifests itself in verifications (+RS) and clarification requests (supportive requests [+NQ], general challenges [-NQ], and exact challenges [-RQ]). In response, the expert acknowledges (+NS) novice contributions and contributes additional ideas in the form of questions (supportive proposals [+CQ] and counter-proposals [-CQ]) rather than statements

(S) or commands (!) to encourage the novices to evaluate them (+ and -). Consider the following example in which a teacher is scaffolding a group of students working on the cruise ship problem.

Scaffolding excerpt [3/22 period 2 table 7

EPA	KC	IF	Person	Actions
0	N	S	NE	Ms. ____________ [teacher's name]
0	N	S		we're confused.
-	N	Q	T	You're confused?
+	C	S	SE	We have a lot of times and hours,
+	C	S		and we kind of have an idea of what we have to compare ,
-	C	S		but we don't know how.
+	C	S		The cruise ship in five hours can go a hundred and ten miles
+	N	Q		right?
+	N	S	T	mm-hmm
+	C	S	SE	and the helicopter in an hour and a half can go a hundred and thirty five miles,
+	N	Q		right?
+	N	S	T	uh-huh.
-	C	S	SE	But then the cruise ship keeps on going,
+	N	Q		right?
+	N	S	T	Right,
+	C	Q		so how far does IT go in an hour and a half?
-	N	Q	SE	What?
+	C	Q		the cruise ship?

+	N	S	T	uh-huh
+	N	S	SE	Oh!
+	C	S		we left in an hour
-	C	Q	T	I mean how much FARTHER does it go in an hour and a half?
+	C	Q	SE	[computes] 33 miles?
+	C	Q	T	So it would be 143 miles out?
-	C	S	NE	about
+	R	S	T	about
+	N	S	SE	OK
+	N	S	T	OK

Since the novices SE and NE always addressed the expert T, the expert took the most turns, even though SE occupied the most floor time. The novice SE produces most of the contributions (C) but requested evaluations from the expert in the form of proposals (+CQ) and supportive additions (+CS) with tag questions (+NQ). In response, the expert acknowledged them (+NS) and contributed supportive proposals (+CQ) and counter proposals (-CQ) to encourage SE to evaluate them. In scaffolding interactions, novices dominate the floor time and contribute a lot (C), but they also ask many questions (Q) of the expert. The expert takes the most turns, acknowledges contributions (+NS) and proposes actions (+CQ and -CQ).

In accepted demonstrations, everyone knows a solution, but one person solves the problem alone. That person solves the problem with chains of supportive additions (+CS), dominating the floor in a few long turns. The others may acknowledge (+NS) a few key actions or engage in an unrelated parallel conversation (+ and -; N). Unlike lectures, there are few verifications (+RS) or clarification requests (supportive requests [+NQ], general challenges [-NQ], or exact challenges [-RQ]). Since everyone is an expert, the speaker does not need to check the audience's understanding with tag questions (+NQ). Consider the following segment in which two students are entering equations into the computer so that it will graph a starburst (lines that go through the origin, see figure 1)

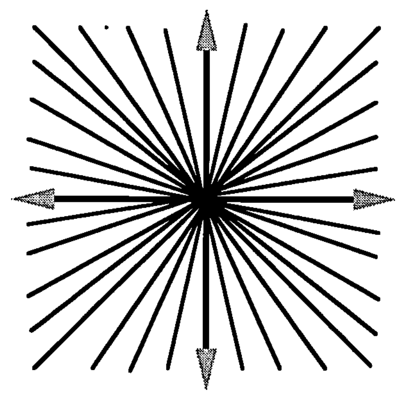

Figure 1. A starburst created by entering equations of the form y=mx into the computer graphing program. The parameter m takes on positive values greater than 1, positive values between 0 and 1, negative values between 0 and -1 and negative values less than -1.

EPA	KC	IF	Person	Actions
0	C	S	MS	[enters y=.9x]
+	C	S		[computer plots]
+	N	S	RA	You're soundin' like –you look comfortable.
+	N	S	MS	I am comfortable.
+	C	S		[enters y=.8x]
+	C	S		[computer plots]
+	C	S		Seven tenths.
+	C	S		[enters y=.7x]
+	C	S		[points to graph, traces some of the flatter lines] It's going backside.
+	N	S	RA	You are tweakin'.
+	N	S	MS	[laughs]

+	N	!	Go, boy.
+	N	!	Go, boy, go.
+	C	S	[computer plots]
+	C	S	[enters y=.6x]
+	C	S	[computer plots]
+	C	S	[enters y=.5x]

MS dominated the floor with a few long turns. Both MS and RA appeared to know the solution to this problem as MS solved it (+CS) alone with a bit of cheerleading from RA (+NS) in a parallel conversation. Neither of them asked any questions (Q) or criticized (-) any actions. MS's playful commands (!) to the computer suggested her ease with the solution. In accepted demonstrations, one person executes a solution using supportive additions (+CS), while the others acknowledge the actions (+NS) or engage in parallel conversations (+ and -; N).

Finally, collaborating experts seamlessly execute successive problem solving moves to produce an automatic joint solution. Unlike the few long turns of a lecture or an accepted demonstration, a joint automatic solution mostly consists of supportive additions (+CS) in many short turns by different people. The participants may also acknowledge (+NS) each other's actions and engage in parallel conversations (+ and -; N). Consider the following example of a group of experts solving the talus slope problem.

[4/21 period 2 table 8 check time, between 10:05 & 10:15]

EPA	KC	IF	Person	Actions
0	C	S	NE	[picks up a stick]
+	C	S	SE	[tilts the box, creating a high pile in the corner, carefully lowers box.]
+	C	S	NE	[starts lowering a stick vertically into the corner.]

+	C	S		[lifts the stick out slowly with a finger at the point where the top of the pile touched the stick]
+	C	S	NW	[slides a ruler closer to NE]
+	C	S	NE	[places the stick against the ruler] (measuring)
+	C	S		Eight and a half
+	C	S	NW	[writes "8.5"] (preparation for calculator computation?)

NE, SE and NW are all building on each other's actions and are contributing appropriate steps to the solution (+CS) without any questions (Q) or criticisms (-). Automatic joint solutions consist primarily of supportive additions (+CS) from many people in short turns. Automatic joint solutions are more efficient than accepted demonstrations if the time saved by parallel contributions exceeds the additional time needed for coordination between participants' actions.[8]

In short, I have described six types of social interaction segments from the two dimensions of knowledge distribution and degree of cooperation (see table 2). If no one in the group knows a solution algorithm in the interaction segment, then they can work relatively independently through piecemeal guessing or cooperate through a joint construction. Groups with at least one individual who knows a solution algorithm can engage in independent lecturing or cooperative scaffolding. Finally, if everyone knows a solution algorithm, then one person may independently display an accepted solution method or they can work together to create an automatic joint solution.

[8]Automatic joint solution segments differ from small scale jigsaw solutions because we expect significantly more coordinating actions in jigsaw interactions to put the fragments together, including discussions about how to coordinate. As discussed earlier, jigsaw solutions with large individual contributions are likely to include many lecture segments.

Table 2. Interaction types and the individual actions that form them (actions listed in decreasing prevalence within each interaction type).

Distribution of Knowledge	Degree of Cooperation: Independent	Degree of Cooperation: Cooperative
All novices	**Piecemeal guessing** Short turns Unresponsive actions (0) Announcement (0CS)	**Joint construction** Short turns Supportive addition (+CS) Supportive proposal (+CQ) Critique (-CS) Counter-proposal (-CQ) Verifications (+RS) Acknowledgment (+NS) Supportive request (+NQ) General challenge (-NQ) Exact challenge (-RQ)
At least one expert and one novice	**Lecture** Expert(s): Long turns, More floor time, More turns Supportive addition (+CS) Supportive request (+NQ) Acknowledgment (+NS) Implementation command (+C!) Denial (-NS) Critique (-CS) Novice(s): Short turns Verifications (+RS) Acknowledgment (+NS) Supportive request (+NQ) General challenge (-NQ) Exact challenge (-RQ) Supportive addition (+CS) Supportive proposal (+CQ)	**Scaffolding** Expert(s): Short turns, More turns Supportive proposal (+CQ) Counter-proposal (-CQ) Supportive request (+NQ) Acknowledgment (+NS) Novice(s): Short turns, More floor time Supportive addition (+CS) Supportive proposal (+CQ) Verifications (+RS), Acknowledgment (+NS) Supportive request (+NQ) General challenge (-NQ) Exact challenge (-RQ)
All experts	**Accepted demonstration** Demonstrating expert: Long turns, More floor time, More turns Supportive addition (+CS) Parallel conversations with problem solving Other(s): Short turns Acknowledgment (+NS)	**Automatic joint solution** Short turns Supportive addition (+CS) Acknowledgment (+NS) Parallel conversations with problem solving

CONCLUSION

I have introduced a multi-dimensional, multi-level framework for analyzing students' social interactions and individual actions during collaborative problem solving. Crossing the dimensions of problem knowledge distribution and degree of cooperation yields six possible social interactions: piecemeal guessing, joint construction, lecture, scaffolding, accepted demonstrations, and automatic joint solutions. At the individual action level, I have constructed a three-dimensional space from the dimensions of evaluation of previous action, problem knowledge content, and interactive form) and located twenty-seven individual actions within that space. Moreover, I have shown that each social interaction consists of particular individual actions in representative segments of student collaborations in an algebra classroom. This paper takes a step towards integrating analyses of individual actions and social interactions. Instead of simply accepting the two levels of analysis as legitimate, this paper begins to show how sequences of individual actions create social interactions. Future quantitative analyses will determine the generality of these claims.

Educators can use this framework both as a collaboration tool and as an assessment tool. Since specific actions constituted particular interaction categories, increased collaboration may result from reducing the actions involved in independent problem solving and increasing those in collaborative work. Finally, teachers can evaluate students' levels of collaboration and understanding as well as the difficulty level of their lesson plans and their curriculum.

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Signature: Ming Ming Chiu	Position: POST-DOCTORAL FELLOW
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Address: 3131 MOORE HALL GSEIS UCLA LOS ANGELES, CA 90095	Telephone Number: (310) ~~825~~ 206-0361
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